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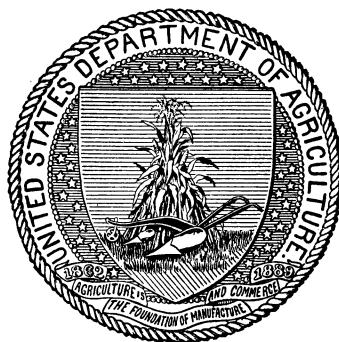
THE CONTROL OF BLOWING
SOILS.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
Washington, D. C., August 21, 1910.

SIR: We have the honor to transmit herewith and to recommend for publication as a Farmers' Bulletin the manuscript of an article entitled "The Control of Blowing Soils," prepared by Mr. J. M. Westgate, Agronomist in the Bureau of Plant Industry, and Mr. E. E. Free, Physicist in the Bureau of Soils.

The rapid extension of agricultural operations into the sections of the United States where the rainfall is so limited as to make the problem of soil blowing a serious one has led to numerous calls for information concerning the best methods of solution. Both the Bureau of Plant Industry and the Bureau of Soils have published technical papers dealing with the respective phases of the problem. It is thought advisable, however, in the present paper, to give the views of both bureaus in a single publication.

Respectfully,

MILTON WHITNEY,
Chief, Bureau of Soils.

G. H. POWELL,

Acting Chief, Bureau of Plant Industry.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE CONTROL OF BLOWING SOILS.

INTRODUCTION.

The problem of blowing soils is important wherever there are considerable areas of bare soil exposed to the continued action of relatively high winds without accompanying rainfall. In the more sandy sections even frequent rains do not suffice to hold the soil in sufficient check to entirely prevent blowing. The most important problem is the prevention of soil blowing on bare fields or on fields so recently seeded that the crops have not made sufficient growth to protect the surface. Other problems, such as the prevention of soil blowing in cuts, embankments, etc., are sometimes important, but in the aggregate are much less so than the more widely extended blowing which occurs on ordinary cultivated fields. Nearly all cases of injury by blowing can be cured or greatly bettered without undue expense if the farmer has an understanding of the practical means of control.

It is only where there is excessive blowing of the soil that damage occurs. There is a normal and moderate movement of the soil by wind, the effects of which are probably more beneficial than otherwise in mixing the soil and renewing the upper surface. It constitutes one factor which tends to maintain the fertility of any particular soil.

NORMAL MOVEMENTS OF THE SOIL.

Careful investigation has shown that the soil is in constant change. Water and wind are always moving soil material from place to place, removing here, depositing there, with a net tendency toward its slow transfer from the land surface into the sea. The share of water in this movement of soil is well known, but that of the wind is less apparent. In the deserts, however, the frequent dust storms and the constant shifting of sand over the surface have in the aggregate great and well-known geologic actions. Similarly, in sand-dune areas, on coasts and elsewhere, the effects of the wind are obvious. Even in the humid regions the wind plays no inconsiderable part in the general process of soil movement, but its actions are here so slow that they usually escape attention and are recognized by

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indirect evidence alone. Among the items of this evidence may be mentioned the well-known tendency of dust to gather in unused rooms, on the beams of barns, and in similar places to which it could have been carried only through the air. Analyses of these various dusts have shown them to be simply ordinary soil, and if enough soil to be noticeable is accumulated in such places much more must be blowing about continually in the open fields. Similarly, partly melted snowdrifts have always a dirty appearance, especially if they have lain for some time. This dirt, too, is blown soil, and much more must be in motion in the summer, when the ground is more fully exposed, though there is then no indicator, such as the snow, to show its presence.

This continual blowing of small quantities of soil is naturally greater on cultivated fields than elsewhere, as there is no protective covering of vegetation. The reality of the phenomena may be shown by a very simple experiment. If any ordinary glass partly full of water be placed for a few days on a fence (or other support) in the midst of cultivated fields, the water will become muddy from soil which blows into it, and this will occur when the wind movement is only normal. On very windy days the quantity of dust collected will be much greater.

The moving of soil by wind and water, and even its final removal into the sea, is not in general harmful. Much good results from this process. Were the soil a stationary thing, and did each particular soil grain remain forever in one place, fertility would rapidly decrease. The removal of plant food materials by plants and in the drainage waters would ultimately take from the upper layers of the soil much of the elements useful to plants. The soil, however, is not stationary; its surface layers are being continually removed by wind and water and the particles carried (mainly by the water) to the sea. In their stead new, unweathered, and unexhausted fragments of the underlying rocks are coming into the soil zone and in their turn are contributing to its fertility. This process of the removal of worn-out soil must of course be properly balanced against the agencies of chemical rock decay and the extraction of nutrients by plants. If the mechanical removal of soil material be too slow, there will be an actual chemical exhaustion. If it be too rapid, there will not be time for the necessary weathering and preparation of the rock fragments which appear from below. Both of these extremes occur in nature, the second far more often than the first, but fortunately both are comparatively rare.

As one of the agents of a properly balanced removal, the wind is frequently of great importance, but even in places where its tendency is not to remove but to leave the surface level unchanged, or even to

cause deposition, it may still have a beneficial influence upon soil fertility. The drift of blown material back and forth will tend to mix with each other all the surface soils of the area affected and may thus supply in some places useful minerals in which the soil there happens to be deficient, but which were present in more than needful quantity in other soils of the area. Similarly, by removing fertile material from deserts and depositing it in other and often distant regions, the wind has built and is building many large areas of soil of great fertility and high agricultural value. Examples of these are the loess soils of China and Central Asia and the "tirs," or black earth, of Morocco. Some of the very fertile loess soils of the Mississippi Valley are probably also wind-deposited.

The normal degree of soil movement by the wind is, therefore, more beneficial than harmful. Local conditions may, however, be such that wind erosion becomes excessive, and grave injury is done to both crops and soil. With the opening up of much land in the arid and semiarid regions, this danger of wind damage has become of vital importance to American agriculture. It is to an outline of the most useful known methods of avoiding this injury that the present bulletin is devoted.

CAUSES OF EXCESSIVE BLOWING OF SOIL.

The two factors involved in the blowing or shifting of the soil by the wind are the strength of the wind and the power of the soil to resist its action. When the wind strength becomes too great for the resisting powers of the soil, blowing will occur. (See fig. 1.)

Some soils blow very easily and are damaged by light winds. Ordinarily, however, the soil has a fair power of resistance, and it is only from heavy winds that serious damage may be expected. The likelihood of damage over any given area will depend upon the frequency of heavy winds there, and especially upon the frequency of such winds during the season (usually the spring) when the soil is least protected by vegetation or snow and most open to attack.

The velocity of the wind is not, however, the only factor which affects the problem. Its direction and constancy, as well as the moisture content of air and soil, etc., are also of importance. For instance, a wind constant in direction from day to day will do far more damage to agricultural land than variable winds, which undo to-day what they did yesterday. Also a moist wind, or a wind following a rain which has left the soil well wetted, will do comparatively little harm.

The resistance of a soil to wind action depends upon its cohesion and its degree of exposure to the wind. The cohesion is to a certain extent controlled by the physical and chemical nature of the soil, but

much more largely by its water content. Thus, a clay soil is less subject to blowing, not so much because clay particles hang together better than those of sand, though this is of some importance, as because the water-holding power of clay is better, and it is therefore more likely to be able to keep itself moist. It is only a dry soil, or one which can be dried by the wind, that will blow seriously. The exposure of a soil is even more important than its cohesion. If the wind is unable to get at the soil there can be no blowing, no matter how dry or loose the soil or how strong the wind. In nature the

degree of exposure depends almost entirely upon vegetation. If a soil is well covered, the lower layers of moving air are entangled in the plants and retarded, and the air next the soil has only a very low velocity. The "wind" does not reach the soil at all. For this reason, and because of the actual holding of the soil by plant roots, a cover of vegetation is a nearly perfect protection against blowing.

It is obvious that both of the soil factors affecting blowing, namely, cohesion and exposure, are



FIG. 1.—Dust storm in the Great Plains region. In this storm, lasting twelve hours, at least one inch of topsoil was removed.

mainly controlled by the water supply. A moist soil is always coherent, and a dry one is only seldom so when loose. Similarly the covering of vegetation (native or artificially planted) which a soil will bear, and hence the degree of protection with which it can provide itself, sustains a direct and closely corresponding relation to the water supply. It is to be expected, therefore, that soil blowing will be an especially serious problem in regions of low rainfall. In the arid region, soil blowing is the rule, while in the humid regions it occurs only in exceptional cases, mainly on sandy soils of very low cohesion and situated in windy regions.

Damage by soil blowing may be and usually is twofold: Directly, to the soil, and indirectly, to the plant or crop covering. The injury to the soil itself is usually through removal, and there are many cases in which the blowing away of the fertile surface layers exposes subsoils insufficiently weathered and filled with humus to be ready for crops. More generally important, however, are the injuries to the crop itself by blowing out or burial, or the direct cutting effect of flying sand grains. The danger is especially great to new seedlings or plantings, since a great proportion of the ground is bare and unprotected. It is no uncommon occurrence for farmers in the arid and semiarid sections to lose an entire crop through the blowing out of the seed or the uprooting, burial, or cutting off of the young plants. After the plants are larger they become not only better able to survive burial or exposure of roots, but also more efficient in covering and holding the soil and preventing its blowing.

CONTROL OF SOIL BLOWING.

MEANS OF PREVENTING DAMAGE.

It is apparent from the facts just stated that the means by which the damage may be prevented or decreased must be, in principle, two: (1) Increasing the cohesion of the soil, and (2) decreasing its exposure to the wind. The cohesion may be increased practically (1) by increasing the water content of the soil, (2) by increasing the amount of humus which it contains, and (3) by modifying its texture, as, for instance, by adding clay or by leaving it in small clods instead of in a finely pulverized condition. The exposure may be decreased (1) by providing a cover of growing vegetation, (2) by leaving the stubble of the last crop still standing on the land, (3) by providing an artificial cover of straw, brush lines (fig. 2), etc., and (4) by planting windbreaks to protect the fields. (See fig. 3.) In addition to the above methods, the roughening of the surface by proper cultivation really protects the finer soil particles from blowing, as they soon become located in the depressions, where the exposure to the winds is much less.

The degree of usefulness of these various general methods of control in any particular case depends upon local conditions of soil character, climate, the lay of the land, etc. All of them are in use under various circumstances and in varied combinations. Indeed, most of the practical expedients employed to prevent blowing act in two or three of these ways, frequently leading to both increase of cohesion and decrease of exposure. Some of the practical expedients may be outlined as follows.

SUITABLE CROPPING SYSTEM.

Where it is possible to do so, the easiest way to prevent wind damage is to plan the use of the land so that it will always be covered with some form of protective vegetation during the season when dangerous winds are to be expected. Whether this can be economically done depends altogether on the climate, the relation to markets, the season in which the windy periods occur, and other factors of the same sort. All of these are so entirely local that a general discussion is impossible. A few general expedients along this line can, however, usually be employed. For instance, if fall plowing is not necessary, the stubble of the last crop should be left on the soil until as late as

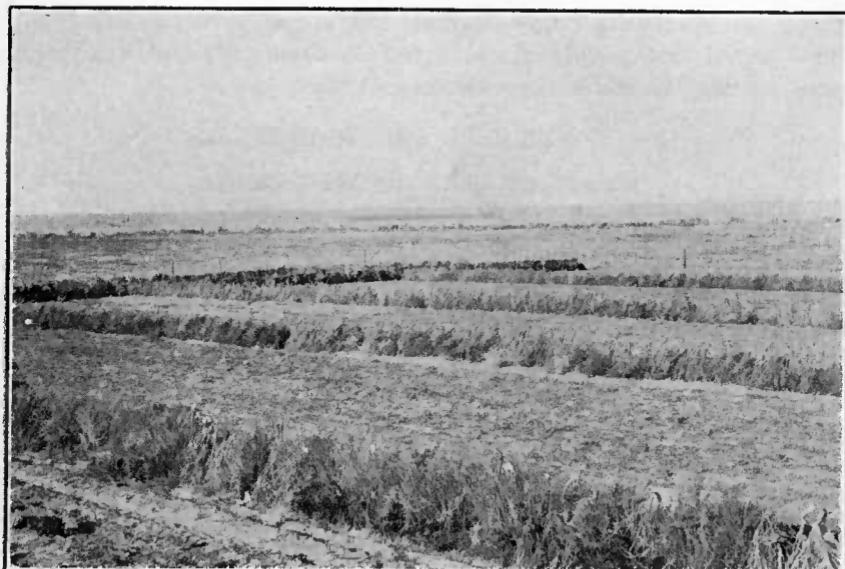


FIG. 2.—Asparagus field protected by low windbreaks of sagebrush.

possible in the spring, or oats or barley may be sowed in the late summer or early fall. The plants will be killed by the frost and will form a protective mat on the soil surface. This will prevent blowing during the winter and early spring.

In other cases it may be possible to combine with a slow-growing crop subject to wind damage a more rapid-growing nurse crop, which forms a cover very soon after seeding and protects the other crop during its early life. Thus a thin seeding of rye or barley may be used in which to introduce alfalfa.^a Another useful method of introducing alfalfa and similar slow-starting crops is to drill in the seed

^a See Farmers' Bulletin 339, entitled "Alfalfa," a copy of which may be obtained without cost upon application to the Secretary of Agriculture.

in high-cut stubble of thinly sown millet or thickly seeded cane or Kafir corn. The advantage of such a procedure is that this stubble does not further rob the soil of moisture as a nurse crop does. When a nurse crop is used, the seeding must be very light, especially in the semiarid regions, as the idea is to obtain just enough nurse plants to hold the soil from blowing and at the same time not to rob the young seedlings unduly of their much-needed moisture.

One cause of blowing which is connected with the cropping system is the use of the summer fallow. This leaves the land fully exposed, and if dangerous winds are to be expected in the summer it is usually

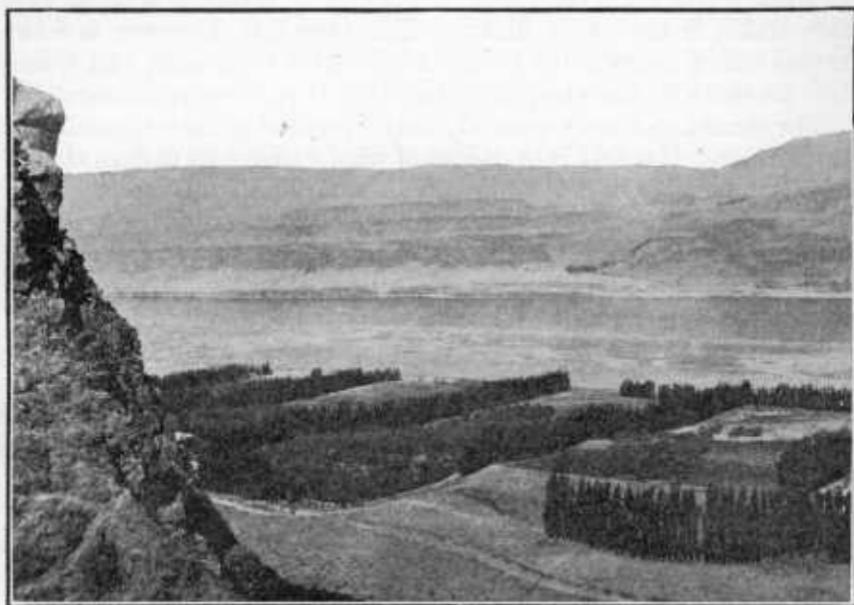


FIG. 3.—Windbreaks of Lombardy poplar trees protecting valuable orchards along the Columbia River in Oregon. The trees have been planted in rows 100 yards apart across the valley. The land between them is entirely free from blowing sand.

better, if enough water is available, to replace the summer fallow by corn or a leguminous crop (preferably intertilled), which is plowed under in the fall. If there is not enough water for this, it may in extreme cases be necessary to let the stubble stand all summer instead of plowing it under in the spring. Any needed harrowing should be done so as to damage the stubble covering as little as possible. Another method is to seed rows of coarse-growing crops at intervals across the fallow field at right angles to the direction of the prevailing winds. Sandy lands are most likely to blow, and these fortunately absorb water readily without spring cultivation.

SUITABLE METHODS OF CULTIVATION.

In preparing a seed bed and in handling a summer fallow, if it be necessary, there are certain methods of cultivation which are frequently useful in decreasing soil blowing. These are specially important in the intermountain regions of the West, where control by the use of crops is usually impossible because of the seasonal distribution of rainfall. The first of these is the compacting of the surface soil by rolling or otherwise. This acts not only in the direct production of a firmer and more resistant surface, but also by bettering the capillary properties of the soil and increasing its capacity to draw water from the lower layers and to maintain a moist surface which is not easily blown. This very fact, however, is what makes rolling increase the surface evaporation so greatly, and therefore prevents its use when conservation of the soil water is important.

The second and more generally useful method is the roughening of the surface. If a field is in danger of wind damage its surface should so far as possible be left covered with clods and the furrows be run at right angles to the direction of the dangerous winds. A rough, cloddy, and furrowed surface acts in the same way as vegetation in preventing the rapid movement of the layer of air next to the ground, thus protecting the soil. When small patches of soil in fields commence to drift with the wind the prompt use of a harrow or other implement to roughen the surface of the blowing areas will usually stop the damage and prevent its spreading to the rest of the field. Opening up furrows with a corn lister across the field at right angles to the prevailing wind will reduce the injury from blowing and also serve to reduce the run-off in case of heavy rains. The maintenance of a rough surface is especially important when a soil mulch is necessary. The recent rapid development of so-called dry farming and the use therewith of the dust mulch have caused a great increase of wind damage. The use of such a mulch means the complete exposure of large areas to the wind for months at a time. This difficulty can be met by maintaining (when the physical nature of the soil will allow) a mulch of small clods instead of fine dust. The efficiency in conserving moisture will be quite as great and the field surface will be rough and not so likely to blow.

KEEPING THE SOIL MOIST.

A moist soil is very little subject to wind action; consequently, if enough irrigation water is available at a time when any serious trouble with blowing threatens, it can be met by immediately irrigating the areas where the soil is being shifted by the wind. Under some circumstances this is a useful procedure, but the water must be applied with care in order to avoid drowning the land. Too much water may be quite as injurious as too little.

ADDING HUMUS.

The more organic matter a soil contains the greater will be its cohesion, not only because of the direct action of the organic bodies themselves, but also because they increase the water-holding power of the soil and hence its ability to keep its surface moist. The presence of humus is therefore a powerful protection against blowing, and many soils can, by humus-forming methods of cultivation, be rendered naturally resistant to wind action. The practical means to this end are usually the plowing under of green crops and the use of stable manure. These measures are nearly always applicable to the sandy trucking soils of the East and in a measure to many of the soils in semiarid and irrigated sections where intensive farming can be practiced. They should be accompanied on all soils subject to blowing by the general policy of leaving on the land and incorporating with the soil the maximum of straw and stubble. The plowing under of a crop with matted roots will have an additional value in preventing blowing because of the binding power of the roots. Freshly turned sod acts similarly, and therefore newly broken sod lands in the semiarid sections are usually comparatively free from blowing for the first two or three years. Thinly sown grasses and similar crops are sometimes of value as nurse crops because of this binding power of their roots.

ARTIFICIAL PROTECTORS.

A much-used method of protecting fields in windy regions is the planting of rows of trees or bushes, or the erection of fences, as wind-breaks. They have the great advantage that they not only protect the soil but also prevent direct injury to the plants by strong winds. However, their cost is relatively high and the percentage of idle land is considerable. They are not, therefore, advisable in extensive agriculture, and practically their use is restricted to the cultivation of valuable crops such as fruits, garden vegetables, etc. In these cases they will nearly always be found profitable for protection to the crop alone, regardless of the existence or nonexistence of danger of wind damage to the soil.

Windbreaks are usually best made of trees or high bushes. The particular species which is most satisfactory will depend in every case on local conditions. The tree selected should be one which is in full foliage and possesses its maximum of wind-resisting power at the season when dangerous winds are to be expected. It should not be of such a nature as to harbor insect pests or to spread by its root system out into the adjoining fields. The design of the windbreak system, the spacing between rows, and between the trees of a row, depends entirely on the species of tree or bush selected, local conditions of topography, strength and direction of winds (especially the

constancy of this direction), crop to be grown, etc. (See fig. 3.) In general, the protective effect of a windbreak will extend to from ten to twenty times its height. Care should be taken that in a region of sand drift the windbreak does not become simply a collector of sand blown in from elsewhere. This can be avoided by planting supplementary lines of bushes or strips of grass outside the regular windbreaks in the direction from which the sand is coming. The best plan, however, is to stop the drift of sand at its source, if possible, as it is usually necessary to do this in the end in any case. Wind-breaks in fruit regions should be so designed as not to stop the air drainage and thus increase the damage by frost.

In a few special cases of very intensive cultivation it may be profitable to employ low, close-set brush lines (see fig. 2), hedges or fences,

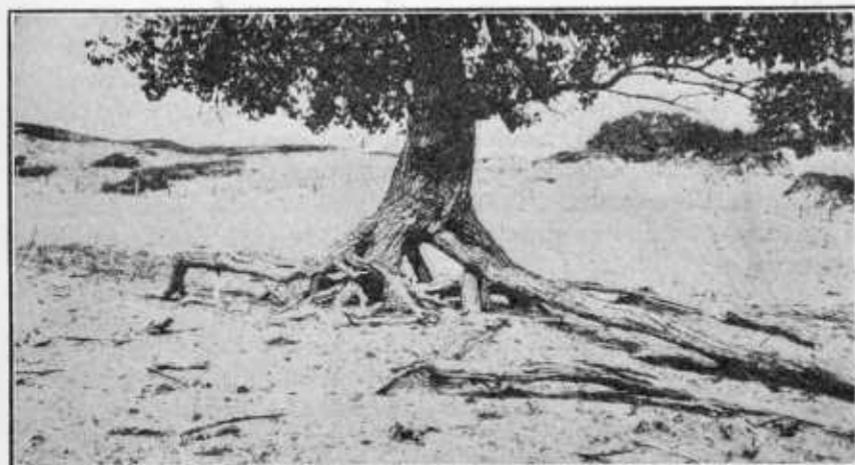


FIG. 4.—Roots of a tree exposed by excessive blowing.

or covers of boards, straw, or other litter applied directly to the soil. The field of usefulness of these is very limited. Where straw is abundant its use may be profitable for ordinary crops. It should be loosely scattered over the soil, using as much as 1 to 2 tons per acre. This, when subsequently turned under, adds to the humus content of the soil and in itself reduces the tendency of the soil to blow.

BLOWING OF SANDY SOILS.

Sandy soils are especially liable to damage by blowing, not only because of their low natural cohesion but also because they are usually well drained and retain water poorly in the surface layer, and hence lack the surface moisture which is a great preventive of blowing on soils composed of finer materials. (See fig. 4.) The danger of blowing must always be borne in mind in reckoning the value of sandy

lands and in designing for them a proper system of cropping. (See figs. 5 and 6.) On them, as on others, the proper adjustment of the cropping system is frequently all that is necessary to prevent blowing. The principles which must govern its design are not essentially different in the case of sandy soils from those outlined for soils in general in the preceding section. It should be noted, however, that the possibility of letting the stubble of one crop stand until the ground is ready for the next is more common on sandy soils than on others. Such soils absorb water readily, and the main reason for fall plowing, namely, the increase of ability to absorb moisture, is in their case absent. The use of windbreaks offers also no new problems on



FIG. 5.—Newly set strawberry field in sandy soil.

sandy soils. Whether they are to be used or not will be decided by factors with which the texture of the soil has little to do, except that of course this texture may be the cause of the trouble which makes some method of control necessary.

Aside from the cropping system, and in case windbreaks are not advisable, the main control method which is applicable to sandy lands is the increase of humus by the addition of organic matter, such as manure or straw or by the plowing under of some green crop. Sands are frequently deficient in humus, and its addition not only aids in preventing blowing but increases the usually low water-holding power and betters the general structure of the soil. Cases are rare in which sandy soils do not need humus, and their cultivation should always

be so carried out as to increase this constituent. Blowing may frequently be prevented by this means alone.

The methods of cultivation (rolling, and the maintenance of a rough surface) advocated for decreasing blowing in general are of little use on sands. The cohesiveness of sand is slight, even when packed, and the formation or preservation of elods is nearly always impossible. Furrows run transverse to the wind may be occasionally of use, but are at best a minor means of control. This is true, also, of artificial moistening. Water runs so quickly through a sandy soil that it is usually impossible to keep the surface moist unless the



FIG. 6.—The same field illustrated in fig. 5, showing the effect of wind on the newly set strawberry plants.

whole soil is saturated—a procedure manifestly impossible if the land is to be used.

There are rare cases in which sandy soils can be bettered by irrigation with silt-laden water. The fine material added in the water decreases the sandiness of the soil, increases its water-holding power, and makes it less liable to blowing. Naturally this procedure is practically possible only where the silt-laden water is easily available, and such places are rare. It has been used in parts of the Rio Grande Valley. There is, however, a natural change which takes place in sandy soils that is of importance in this connection. Blown sands

are usually very clean and contain only small amounts of finer material, the reason being that this fine material is blown away as fast as formed. If, however, the soil be protected from wind action, and if it be at the same time exposed to weathering under ordinary surface conditions, the fine material formed by the natural breaking up of the sand grains will remain in the soil. The gradual accumulation of this fine material will render the soil progressively less sandy. This natural betterment of protected sands is very important in dune fixation and in the protection of wind-exposed sandy soils generally. Each year that the sand remains fixed it becomes better able to protect itself and to resist wind attack.

BLOWING OF NEWLY CLEARED LANDS.

Some of the most injurious cases of blowing so far met with in this country are those which follow the clearing of new land for irrigation

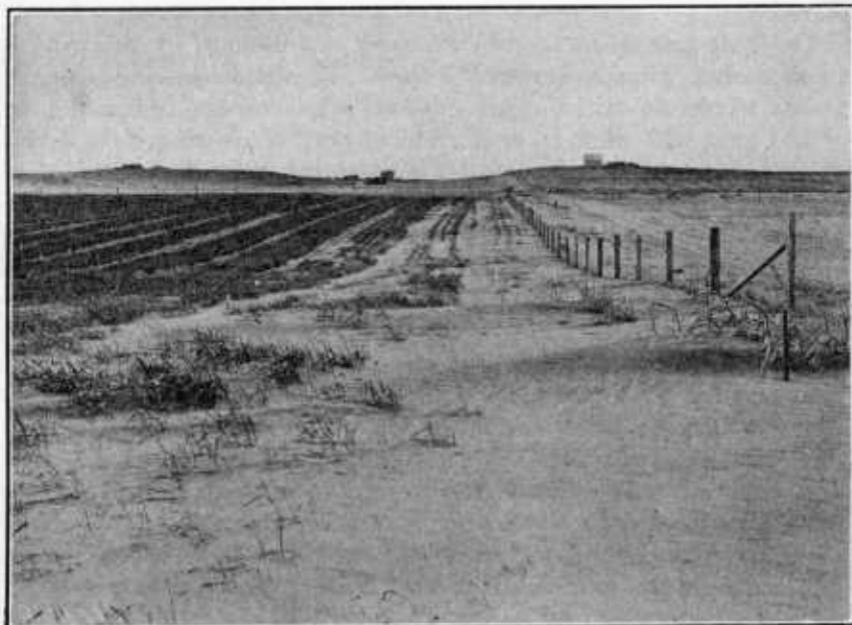


FIG. 7.—Young orchard injured by an incursion of sand from an adjacent newly cleared field.

in the desert regions of the West. (See fig. 7.) These soils are often loose in texture, frequently sandy, and nearly always low in humus. They are therefore unusually susceptible to wind action and are protected from complete removal only by their native cover of bunch grasses, sagebrush, creosote bushes, etc. With the recent increase of irrigation in these regions much of the native vegetation has been removed, in many cases with most disastrous results. The drifting of

the soil becomes immediately so bad as to practically prevent any useful agriculture. Nor is the damage confined to the land which has been cleared. Sand from this land will blow onto other fields, where by proper precautions the blowing has been avoided, killing the crops, filling irrigation ditches, and damaging the soil. A careless farmer may thus easily ruin not only his own land, but that of his neighbors as well.

Once this condition has been allowed to arise it requires much time, expense, and labor to correct. By proper foresight, however, and by the use of necessary precautions to prevent the start of drift, the danger can be largely avoided. Prevention of injury is far cheaper than the subsequent reclamation. It should be remembered also that the danger is largely one which accompanies the beginning of cultivation. Two or three years' use of the land, blowing being prevented and attention paid to the production of humus, will usually so improve the soil that wind damage is much less to be feared.

The best general method of avoiding this damage by the wind is to clear always in small areas at a time. Wholesale clearing generally means wholesale drift of such exposed sandy areas. When the lay of the land will allow it, a convenient way of clearing is to divide the field into strips 20 to 30 feet wide and transverse to the usual wind direction. Only the alternate strips are cleared, and not until these cleared strips are brought into cultivation and a satisfactory stand of some crop obtained on them are the remaining uncleared strips cleared in turn. By this scheme the strips first cleared are protected by the strips of native vegetation on either side, while those of the second set, when cleared in their turn, are protected by the crop on the first cleared strips. There is, of course, the disadvantage that the clearing must be done in two sections and is therefore less economical, and that for the first year or two there is much idle land, and cultivation is difficult and expensive because broken by the uncultivated strips. Experience has shown, however, that these disadvantages are outweighed by the avoidance of blowing. In the sections where there is a good natural grass covering, a comparatively narrow strip of sod may be left at suitable intervals, which may be allowed to remain indefinitely if necessary. In the same way a relatively narrow strip of sagebrush may be left at intervals without seriously reducing the crop-producing areas so protected. In extreme cases such narrow strips may be left permanently uncultivated, or may later be cleared and put into alfalfa.

There are cases, however, in which the leveling necessary for proper irrigation makes impossible this method of clearing in strips. In such places the difficulty can frequently be met by planting

a quick-growing crop immediately after clearing. If it be arranged to allow time for the growth of this crop between the time of clearing and the season of dangerous winds, all trouble can usually be avoided in this way. Rye has been found very useful as such a cover crop. Where the native vegetation is of a character to yield much brush when cut and dry, this brush may be saved after clearing and spread loosely over the cleared land to prevent blowing until a crop has had time to start. In some cases also it may be possible by continued irrigation following clearing to keep the soil moist and thus prevent blowing. Other expedients will be suggested by local conditions. The important point is that farmers intending to clear and cultivate such lands should recognize the danger and prepare to meet it before clearing is commenced. Once the land has been successfully gotten under cultivation attention to the production and maintenance of humus will usually prevent further trouble.

BLOWING OF OTHER SOILS.

On less sandy soils—loams, silts, etc.—damage by blowing is much less frequent and the places where blowing occurs are found largely in the semiarid regions and are more or less directly caused by the dust mulch, the summer fallow, and similar procedures employed as aids toward the conserving of the limited water supply. With the recent rapid spread of agriculture in these regions and the great increase in the use of these methods of moisture conservation, the number of cases of serious blowing has greatly increased. In these cases it may be impossible entirely to prevent wind damage without at the same time suffering a fatal loss of water. The damage can, however, usually be minimized by designing the scheme of farm management with this end in view. The leaving of the stubble, the use of nurse crops, and the other methods outlined will frequently be found valuable in combination and with modifications suited to local conditions. Whether a green-manuring crop shall replace the summer fallow must be decided largely with relation to the water supply. Such a crop will not only prevent wind erosion (usually severe in the case of the summer fallow), but will in nearly every case be of other benefit to the soil. It may, however, use so much of the meager supply of water that its use is impossible.

As above described for sands, and indeed for all soils subject to blowing, the addition of humus is a valuable and not-to-be-neglected expedient. Usually, however, loams and silts are not so deficient in this constituent as are sands.

The expedient which finds its special application on loams and silts is the maintenance of a rough surface. On such soils this procedure is comparatively easy. Clods will hold together and furrows retain their shape much better than on more sandy soils. On fields subject

to blowing clods should never be broken up until the time of seeding and not then unless it is absolutely necessary to do so to insure the proper germination and growth of the crop. Furrows when used should be run at right angles to the prevailing wind direction, and harrowing or shallow disking, also transverse to the wind direction, is often of use. As already stated, a mulch, if used, should be as far as possible of clods rather than entirely of dust.

In addition to silt soils of the ordinary types, there are in many parts of the Western States valuable soils composed in great part of volcanic ash. Because of the irregular shape and "lightness" of their component particles these soils are unusually susceptible to blowing, and frequently need to be artificially protected from the wind either by windbreaks, light covering of straw, or covers of vegetation during the windy season. The addition of humus, rough-surface cultivation, and the various other expedients previously suggested will be found of use. The addition of humus is especially valuable. Fortunately each year of cultivation makes these soils better able to protect themselves. Volcanic ash is easily disintegrated, and especially so under cultivation. Fixation for a few years, with proper attention to the addition of humus, will usually so change the texture of the soil and so increase its cohesion as to greatly decrease, if not entirely remove, the danger of blowing.

MISCELLANEOUS PROBLEMS.

Although the principal problems of the control of soil blowing are in the sections of limited rainfall and on loose and incoherent sands, yet there are even in the humid sections many local problems which merit attention. While these special problems may be relatively unimportant, yet in the aggregate over the entire country their seriousness is not to be underrated.

PROTECTION OF IRRIGATION DITCHES, EMBANKMENTS, ETC.

The expense incident to the opening up of an irrigating ditch is so great that it is important that all means be used to prevent the filling up of the same, either by the blowing in of the soil from the immediate banks or by the blowing of soil from adjacent areas. While the growth of trees or shrubs may serve to bind the immediate ditch banks, yet such a hedge may prove injurious by causing the deposition in the ditch of blown sand which would otherwise be carried clear across. The use of willows is objectionable owing to their tendency to spread into the ditch itself. The proper solution of this difficulty would appear to be the use of some low-growing plant

which will form a dense mass near the surface but offers little obstruction to the wind and causes but little deposition of the sand which it carries. Protection from blown-in sand can be provided by the erection of a suitable windbreak at such a distance from the ditch that sand drifts which may form around it will not prove troublesome. Better still, the sand drift may be stopped at its source. Tamarisks, Russian artemisias, and willows can be used for this windbreak, though some irrigation is usually necessary, especially when establishing them. Where the ditch runs through the sagebrush territory it may be sufficient to leave a narrow strip of uncleared sagebrush on each side. When other means fail the banks may be seeded with rye, which can be followed by some permanent perennial grass if the same be available, or the rye can be seeded annually.

The protection of earth dams or embankments, the sides of railway cuts, etc., may be similarly effected, though here the damage is more likely to be from washing than from blowing, and is outside the province of this bulletin.

PROTECTION OF ROADS.

The protection of roadways is occasionally necessary. Erosion, both by wind and by water, has in many recorded instances resulted in the lowering of highways until they are sometimes many feet below the level of the surrounding country. In the extensive loess areas of China the roads have sunk sometimes to a depth of 50 feet, with the sides approaching the vertical. In our own country it has been noted in eastern Washington that the roads have been lowered 2 or 3 feet within recent years, apparently by the blowing away from the roadbed of clouds of dust raised by passing vehicles. These injuries are so slowly produced that preventive measures are usually impracticable. The use of windbreaks along the roads may sometimes be advantageous, but is open to the disadvantage of causing deep snowdrifts if the country be subject to heavy winter snows.

INJURIES TO PASTURES.

Wherever pastures are located on soils of a sandy nature or others which have a tendency to blow there is always danger of starting blow-outs which may increase in size and work the destruction of considerable areas of valuable grazing land. (See fig. 8.) Not only are the plants uprooted as the blow-out enlarges, but the other vegetation in the path of the drifting soil or sand is buried. These blow-outs are very apt to follow overgrazing, which may so reduce the vitality of the grasses that they will succumb during unfavorable seasons and allow the soil to commence blowing. Obviously the best practice is to abstain from overpasturing. When the injury is done it can best

be cured by removing as large a proportion of the stock as possible and checking the expansion of the local blow-outs by brush coverings, under which rye may be started, to be followed by grasses, low shrubs, or trees. Exposed spots which experience shows to be especially susceptible to blowing should be put permanently into trees, shrubs, or some form of vegetation which will not be grazed.

BLOWING OF FROST-LOOSENERD SOILS.

A kind of blowing occasionally met with, though rarely of importance, is the winter blowing of frost-loosened soils in the Northern States. This can usually be prevented by leaving the stubble on the

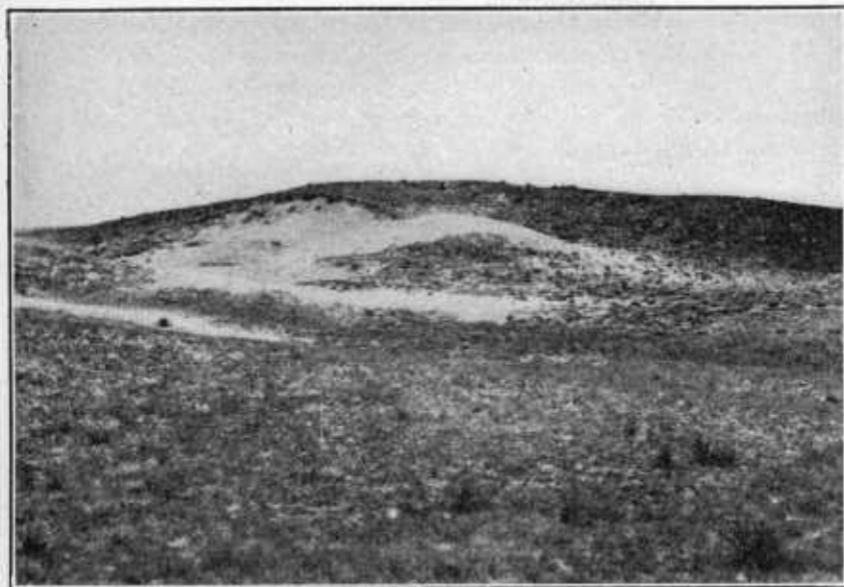


FIG. 8.—Blow-out in a sandy pasture induced by overgrazing and trampling, followed by strong winds.

land during the winter, or, if fall plowing be thought necessary, by leaving the field with a rough surface. The stubble or the rough surface will tend to retain the snow and the snow will protect the soil, as well as itself furnishing a valuable source of water supply.

BLOWING FOLLOWING TIMBER CUTTING.

Some lands are so exposed or so sandy that they can be prevented from blowing only by a permanent cover of timber or shrubbery. On such the cutting of the native timber is frequently followed by the formation of blow-outs and the desolation of the entire area. These cases come more properly under the well-known sand-dune problem, the means of handling which are outlined in the suc-

ceeding pages. In such cases, as with many excessively exposed soils of mountains and sea beaches, cultivation in the ordinary sense is impossible.

CONTROL OF DRIFTING SAND AND SAND DUNES.

INJURY FROM DRIFTING SANDS.

In many places, especially in deserts and on lake and sea beaches, there are large accumulations of sand which the wind has blown into great drifts or dunes, sometimes more than a hundred feet in height. These have a tendency to shift their position slowly, burying everything in their path, and where the movement of such sand dunes



FIG. 9.—Planting beach-grass to protect Cape Cod Harbor (Massachusetts) from drifting sand dunes.

threatens valuable property the problem of their control is of great moment. Along seashores the harbors are especially liable to danger from this injury. Where railroads and highways are forced to follow the shoreline or river course along which such dunes occur the problem of keeping the sand off the roadbed is very serious. An aggregate of over \$50,000 has been spent in protective devices for the protection of Cape Cod (Massachusetts) Harbor alone. (See fig. 9.) In Europe large sums of money have been spent in dune control, especially along the Baltic Sea in Germany and in Gascony along the French coast.

On the farms subject to injuries by shifting sand dunes the problem is important, not usually because of the value of the dune lands themselves, but because of the danger of the destructive movement of dunes over fertile soil, orchards, or farm buildings. The farmer in the arid regions especially finds it often necessary to control a sand dune because of its menace to the other areas of his farm.

DEVICES FOR THE CONTROL OF DRIFTING SANDS.

Trees or shrubs are usually the only form of vegetation capable of producing permanent fixation of dune sands, and the ultimate end arrived at by nearly all systems of control is the establishment of a

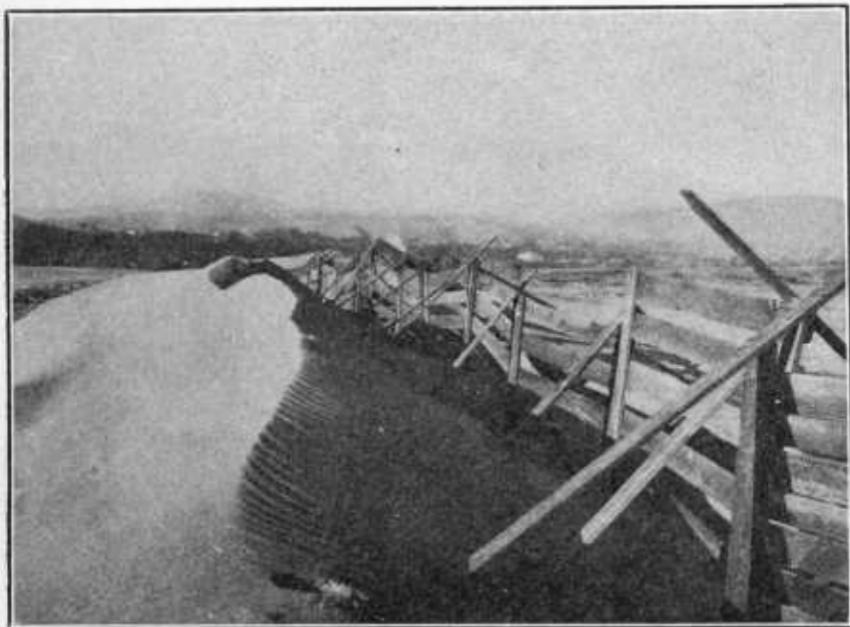


FIG. 10.—Sand fence holding an otherwise shifting sand dune in place.

forest or tree covering. It is manifestly impossible, however, to directly establish young trees upon the exposed areas. A considerable preliminary protection is necessary. Such mechanical devices as brush lines, scattered brush, straw, or refuse material of any kind all tend to temporarily hold the sand until grass or other herbaceous vegetation can be established. This herbaceous vegetation will usually give sufficient protection to the young trees while they are obtaining growth enough to cover the ground and constitute in themselves a permanent protection. A method which has proven very effective along the Columbia River and elsewhere is to make a preliminary seeding of rye and protect it by a thin scattering of straw

over the surface. At 10-foot intervals among the rye are put sets of permanent sand-binding grasses which spread by underground rootstocks. These grasses are usually to be found growing on the sandy areas in the neighborhood. These spread and establish a permanent grass covering by the time the rye has ceased to be effective. If a good stand of rye is secured it will usually reseed itself for several years. Following the permanent grasses and by their protection, it is usually possible to establish shrubs and trees at suitable intervals. The tree selected should be of a kind which will furnish a dense growth near the surface of the ground rather than a tall trunk, branchless at the bottom. Where there is plenty of moisture in the soil, willows are very well adapted to this purpose. Cottonwoods are of perhaps more universal application. Pines have been much used abroad, but do not seem to be adapted to American conditions.

For checking the movement of a dune, either as an end in itself or as a means toward forestation or fixation with grasses or other plant covering, a particular form of fence has proved very useful. This is constructed after the fashion of an ordinary board gate, with horizontal boards and openings the same size as the boards. This is placed on the crest of the advancing dune and braced in two directions with poles. As the fence becomes buried it is raised at intervals; and since the fence checks the advance of the crest of the dune the advance of the entire dune is stopped. (See fig. 10).

These fences have been in practical use in checking the advance of dunes along the Columbia River, where they were a danger to the railroad right of way and to valuable irrigated farm lands. Such fences have also proved very valuable in retarding the formation of large blow-outs and in filling them with sand blown in from elsewhere.

SUMMARY.

The effect of wind in blowing soils is in the aggregate of much importance in the humid sections, although the process is slower and less obvious than in the drier regions. The good effect of the shifting of soil lies in the mixing of the soil particles and the renewing of the surface layers. The evil effects occur principally in the arid and semiarid regions. The most practical means of control lie in the proper adjustment of the cropping and tillage system so as to provide at the critical stages a protection of either plants or rough surface soil. Increasing the humus content of the soil also reduces the danger of blowing. When the land is used for intensive farming, brush lines, straw covering, hedges, or windbreaks of trees constitute the most efficient protection.



